1.00 INTRODUCTION

1.10 AUTHORIZATION

The Board of Health of the Town of Shrewsbury (the Town) contracted GZA GeoEnvironmental, Inc. of Norwood, Massachusetts (GZA) to conduct a feasibility study for the restoration of Jordan Pond. Funding for this study was provided through a grant by the Commonwealth of Massachusetts through the Department of Environmental Management's (DEM) Lakes and Ponds Program. Authorization for GZA to proceed was granted by the Town on September 26, 2002.

1.20 PURPOSE

The purpose of this study is to examine the potential for the restoration and improvement of water quality and other conditions at Jordan Pond relative to human usage and aquatic habitat. Phase 1 of the study includes a review of existing information; a biological survey; bathymetric mapping; sediment mapping; surface water, stormwater, and sediment sampling to characterize the nutrient and bacteria loading to the pond; waterfowl control recommendations; a review of potential archeological issues related to dredging, and recommendations on increasing flow through the pond. Based on the data collection and analyses conducted in Phase 1 of the study, a Pond Management Plan has been developed. The Management Plan seeks to address the Town's request for recommendations to improve the aesthetic quality of the pond in terms of nuisance aquatic weed reduction, water clarity, and odor reduction to promote the use of the pond for recreational activities such as fishing, boating, and ice skating. The Management Plan also includes GZA's opinion regarding the feasibility of re-opening the swimming beach at Jordan Pond.

In Phase 2 of the study (not included in this report), GZA will explore in detail proposed methodologies for in-Pond remedies and expected outcomes. In accordance with the Town's recommendations following the review of the Jordan Pond Management Plan prepared in Phase 1 of the study, GZA's Phase 2 assessment may focus on dredging or alternative methodologies to address the particular needs and constraints associated with the work at Jordan Pond. Work conducted in Phase 2 of the study will be summarized in a separate Feasibility Study Report.

Ultimately, the Jordan Pond Watershed Association, the greater community, and the Town will need to weigh the advantages, disadvantages, and costs of the recommendations made in this report. The final decision regarding the desired level of restoration is a judgment that depends on the desires of the users of the Pond and other interested stakeholders.

1.30 SCOPE

To meet the purposes of the project and in response to the Request for Proposals issued by the Town, Phase 1 of the Jordan Pond Restoration Study has addressed the following tasks:

Task 1: Review Of Existing Information and Biological Survey

GZA met with the Town and Watershed Association on October 16, 2002, for a kickoff meeting and to gather and review available existing information. GZA utilized available GIS-based data and conducted a field reconnaissance of the Pond. The results of these efforts are contained in Sections 2.00 and 3.00. GZA also observed and mapped aquatic plant coverage in the Pond and noted other plant and animal species present in the area of the Pond, as discussed in Section 4.00 of this report.

Task 2: Bathymetric Survey

GZA performed a bathymetric survey of Jordan Pond and mapped the underwater contours of the bottom of the Pond. Information on this process and the results there of are presented in Section 3.50. General sediment thicknesses and textures were also mapped.

Task 3: Water Quality Sampling

GZA conducted two rounds of water quality sampling at Jordan Pond, under "typical" (dry) and "wet" conditions, to assess the physical, biological, and chemical parameters of the water both in the Pond and in the surface water runoff which enters the Pond. GZA prepared a site-specific Quality Assurance Project Plan (QAPP) for the water quality sampling program. The results of the water quality sampling are presented and discussed in Sections 3.60 and 3.70.

Task 4: Assessment Of Nutrient And Bacteria Loading

GZA created a customized watershed nutrient loading model for the Jordan Pond watershed using the Generalized Watershed Loading Functions (GWLF) model developed by Haith, Mandel, and Wu (1992). GZA also created a customized spreadsheet bacteria loading model. The results of these two loading models were used to estimate nutrient and bacteria budgets, and were also coupled with an in-pond water quality model developed by Chapra (1997) to assess the water quality within Jordan Pond. The in-pond model was also used as a management tool to evaluate the potential relative benefits realized via implementation of one or more watershed and in-pond management options. A discussion of the modeling efforts and an assessment of nutrient and bacteria loading can be found in Section 5.00.

Task 5: Analytical Testing Of Sediment

GZA collected three samples of Jordan Pond sediment and analyzed the sediment for a suite of physical, chemical, and biological parameters. Additional tests were performed on a composite sediment sample to assess the quality of dredge material and to evaluate its suitability for reuse or disposal. Discussion of sediment is contained in Section 3.80.

Task 6: Waterfowl Prevention Recommendations

GZA researched and assessed methodologies for preventing waterfowl from congregating on the shoreline and in Jordan Pond. Through this research and past experience at similar sites, GZA has recommended waterfowl prevention options. A discussion of waterfowl control methodologies is presented in Section 6.00.

Task 7: Recommendations to Increase Outflow

GZA has assessed the potential impacts and overall feasibility of both augmenting inflow and increasing outflow to Jordan Pond. As part of this assessment, an annual water budget was prepared for Jordan Pond, and water quality models were used to assess the potential impacts of increasing flushing at the Pond. A discussion of this assessment and GZA's recommendations pertaining to inflow/ outflow augmentation is in Section 7.00.

Task 8: Overall Management Plan Development & Recommendations

GZA has prepared an overall management plan for Jordan Pond and its watershed which summarizes the findings of the data collection, research, modeling, and analyses, and provides recommendations for the restoration of Jordan Pond. A discussion of watershed management options is presented in Section 8.00, a discussion of in-pond options is presented in Section 9.00, and Jordan Pond management recommendations are presented in Section 10.00.

This report is subject to the limitations set forth in **Appendix A**. A compete list of references used in the preparation of this report is included as **Appendix B**.

1.40 ACKNOWLEDGEMENTS

The project team for the Jordan Pond Restoration Study was comprised of individuals from a number of disciplines and organizations. GZA would specifically like to acknowledge the contributions of Nancy Allen and Bob Moore from the Shrewsbury Board of Health; Bruce Card from the Board of Selectmen; Brad Stone from the Engineering Department; and State Representative Karyn Polito. GZA would also like to thank the members of the Jordan Pond Watershed Association, including Ralph Kimball, for all of their help. Their participation throughout the implementation of the pond restoration plan and in the future is critical to the success of any effort.

2.00 PREVIOUS STUDIES

Jordan Pond is an important resource which serves a variety of hydrologic, recreational, and environmental purposes. Water quality sampling has been conducted by the town at Jordan Pond at varying time intervals since 1957. The primary constituents sampled include total and fecal coliform indicator organism levels, and the primary goal of the Town's sampling program has been to evaluate the Pond's suitability for swimming. Information in the Town's files indicates that Jordan Pond has been treated with multiple applications of herbicides and pesticides over the years, including two complete reclamations, conducted in 1957 and 1965, when the chemical rotenone was applied to the Pond. Based on this historical data, it is apparent that the water quality problems at Jordan Pond are not recent in origin. Concerns with nuisance levels of aquatic plants, algae, and bacteria in the Pond may stretch back half a century or more.

Concerns over elevated levels of bacteria in the Pond have, in the past, led the Town to target on-site septic systems in the Pond's watershed. Over the past 30 years, the Town has made a concerted effort to identify and require repairs to septic systems in the area. In 1994-1995, two studies were conducted for the Town by Fugro East, Inc., entitled "Septic System Contamination Evaluation for the Jordan Pond Watershed, Shrewsbury, Massachusetts" and "Storm Water Contamination Investigation for the Jordan Pond Watershed, Shrewsbury, Massachusetts." The first study identified nearby septic systems and evaluated the impacts of these systems on the bacteria levels within Jordan Pond. Fugro concluded that fecal coliform contamination from septic systems was likely, but not the primary cause of water quality in the Pond failing to meet contact recreation standards. "High FC values in the pond are probably a consequence of other sources." The second study included a delineation of the watershed and a mapping of the storm water and surface water drainage networks. In this report, it was concluded that "septic system and/or sewage problems were an unlikely cause of the concentrations of phosphorus and nitrogen in the stormwater."

The Massachusetts Department of Environmental Protection has developed a draft TMDL study for Jordan Pond, set forth in *Draft Total Maximum Daily Loads (TMDLs) of Phosphorus for Selected Northern Blackstone Lakes.*[1]

Additional anecdotal information on the history of Jordan Pond was provided by members of the Jordan Pond Watershed Association, at the project kickoff meeting on October 16, 2002. Many of the Association members are long-time residents of the area. At this meeting, it was noted that "swimmer's rash" was associated with swimming in Jordan Pond in the past. The presence of a so-called "Indian Wall" in the Pond was noted, and the raising of the Pond Outlet Channel during the installation of the sewer line was discussed. A full summary of the meeting is contained in **Appendix C**.

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[1] Commonwealth of Massachusetts, Department of Environmental Protection, Division of Watershed Management. 2001. Draft Report MA51004-2001-3.

3.00 POND AND WATERSHED CHARACTERISTICS

3.10 GENERAL DESCRIPTION AND LOCATION

Jordan Pond is a small, urban, natural pond located entirely within the Town of Shrewsbury, Massachusetts. The Pond appears to be a “kettle pond,” which is a type of pond formed when sediment was deposited around a glacier fragment at the end of the last ice age. Jordan Pond is fed by stormwater drainage, surface water flow, and groundwater flow. Outflows from the Pond flow into nearby Lake Quinsigamond. No named watercourses currently drain into Jordan Pond. A historic map dated 1887 shows a stream flowing into Jordan Pond from the north, whereas another historic map dated 1939 no longer shows this stream. The Pond is shown on the Marlborough, Mass. 7.5 x 15 minute USGS topographic quadrangle maps. The Pond is in Worcester County, Massachusetts, at approximately Latitude 42.269°N and Longitude 71.747°W. **Figure 3-1** is a locus map which shows the general location of the Pond, and **Figure 3-2** is an orthophotograph locus map showing the location of Jordan Pond and its contributory watershed.

3.20 CLIMATE

The climate in the Jordan Pond area is typical of central Massachusetts. Data is available from Worcester, MA climate station operated by NOAA at the Worcester Airport. It should be noted that the airport is at elevation 1,010 feet, which is approximately 650 feet higher than the normal pond water surface level. A summary of the most important climate statistics is shown below:

Temperature	
Average Annual Daily Maximum:	55.7°F
Average Annual Daily Minimum:	37.6°F
Precipitation	
Mean Annual Water Equivalent:	47.75 inches
Mean Annual Snowfall:	46.80 inches
Evaporation	
Mean Annual Lake Evaporation:	25.97 inches

3.30 WATERSHED DESCRIPTION

Jordan Pond collects flow emanating from the north via two 30-inch stormwater drainage pipes in addition to twin PVC pipes directly draining Ridgeland Street. Groundwater flow and surface runoff from the east, south, and west, also add inflow to the Pond. Outflow from Jordan Pond is conveyed as surface flow in a shallow, natural outlet channel to Lake Quinsigamond. Groundwater flow out of the Pond is also likely in the direction of Lake Quinsigamond. The watershed topography includes numerous, small hills of glacial origin. **Figure 3-2** shows the boundaries of the watershed. Key watershed characteristics are listed below:

Total Watershed Area:	195 acres
Watershed to Pond Area Ratio:	9.3:1
Total Watershed Maximum Length:	1.2 miles
Total Watershed Maximum Width:	0.4 miles
SCS Composite Runoff Curve Number:	73.8

The watershed which supplies Jordan Pond with runoff consists largely of urban areas which support industrial, commercial, residential land and land uses, as well as a sizable fraction of wooded land. **Figure 3-3** shows the land uses in the watershed area. Based on the land use map, topographic data, and other information the runoff characteristics of the watershed were calculated. The calculations are shown in **Appendix H** and key results are listed in **Table 3-1**. The watershed land use is approximately 60 percent residential, 30 percent forested, and 10 percent commercial, and includes a portion of State Route 9, a major thoroughfare.

Jordan Pond is not a source for public water supply. However, there are multiple public water supply groundwater wells nearby that very likely tap aquifers which are hydraulically connected to the Pond. **Figure 3-4** shows public water supplies, DEP Zone II's (which indicate a well's potential area of influence), interim wellhead protection areas, aquifers, and groundwater discharge points.

No wetland areas are shown on the Mass GIS Database in the watershed, as shown on **Figure 3-5**, but wetland resources are certain to exist. Wetland delineations would likely include areas around the Pond rim, areas along the drainage course entering the Pond on the northeast side and potentially areas within the Pond outflow channel. There are no Areas of Critical Environmental Concern or Certified Vernal Pools (MassGIS 2001) in the watershed, as shown on **Figure 3-6**, but there are at least four potential vernal pools near the Pond. The predominate soils in the area are glacial outwash sands and gravels which are well suited for groundwater storage and transmission[2]. Till and bedrock make up the remainder of the surficial geology in the watershed, as shown in **Figure 3-7**.

3.40 POND DESCRIPTION

Jordan Pond was probably originally formed approximately 15,000 years ago during the last retreat of glaciers at the end of the Pleistocene ice age. Jordan Pond is likely a kettle pond which formed as outwash material was deposited around a stranded piece of glacial ice. When the ice melted, it left behind the void which became the lake. In many instances at kettle ponds similar to Jordan Pond with no perennial surface water inflow (i.e.: primarily groundwater fed), the Pond water surface level is largely dictated by the regional groundwater elevation. The pertinent characteristics of the Pond are shown below:

[2] Based on Estimated Average Annual inflow volumes.

1. Normal Water Surface Elevation[3]: 362.5 feet
2. Length of normal pool: 1300 feet
3. Max Width of normal pool: 850 feet
4. Normal pool storage volume: 150.6 acre-ft
5. Normal pool surface area: 20.93 acres
6. Average depth (at normal pool): 7.2 feet
7. Max depth (at normal pool): 9.3 feet
8. Residence time: 0.42 years
9. Flushing rate: 2.4 exchanges/year

3.50 BATHYMETRY & SEDIMENT THICKNESS

On November 14, 2002, CR Environmental, Inc. (CR) of East Falmouth, MA, under subcontract agreement to GZA, conducted a detailed bathymetric survey in Jordan Pond. The data was used to create a bathymetric map of the bottom of Jordan Pond, shown in **Figure 3-8**. Area/capacity characteristics of the Pond were computed by using the depth contours generated by the bathymetric mapping. **Figure 3-9** shows the depth-area and storage-area curves for Jordan Pond. **Figure 3-10** shows the depth to probe refusal from the water surface. By comparing the depth to refusal with the depth to the Pond bottom, the thickness of the soft sediment was mapped, as shown in **Figure 3-11**. The survey methods are described in **Appendix D.**

Jordan Pond was found to have relatively steep sides all around the reservoir rim, sloping down to a relatively flat bottom of approximately 8- to 9-feet across most of the Pond. A small underwater "island" was found on the west side of the Pond and a similar underwater "peninsula" was noted on the east side. The alignment of these two features is in proximity to the reported location of the "Indian wall." No other indications of the "Indian wall" were found during the survey.

The soft sediment was found to have a minimum thickness in excess of 12 feet on the north side of the Pond. Over the rest of the Pond, the maximum soft sediment depth is approximately 8 to 9 feet in the center, becoming thinner towards the shoreline. The average soft sediment thickness over the whole Pond is greater than 5.4 ft.

3.60 LIMNOLOGICAL CHARACTERISTICS

GZA collected a limited amount of limnological and related water quality data during the course of the present study. Locations of GZA data collection points are shown on **Figure 3-12**, and water quality data is presented in **Table 3-2**. From the limited data collected under the present study, historical data, site reconnaissance, and anecdotal evidence, it appears that Jordan Pond is a hypereutrophic waterbody. This means that the Pond is prone to frequent algal blooms and has characteristics which are highly favorable for aquatic vegetation.

[3] All elevations refer to the National Geoditic Vertical Datum (NGVD). Elevations are approximate, based on USGS topographic maps, and were not verified in field.

Surface water samples during "typical" conditions (little to no precipitation in the five preceding days) were collected by CR and GZA at SW-1 and SW-2 on September 26, 2002. Water quality profile data were taken at these and three additional locations throughout the pond (**Figure 3-12**). On October 16, 2002, GZA collected "wet weather" (significant precipitation in previous 24 hours) surface water sample at SW-1G and stormwater samples at SWO-1 and SWO-2. All sampling was conducted in accordance with a site-specific Quality Assurance Project Plan (QAPP), attached as **Appendix E**. All laboratory reports are attached as **Appendix F**. Profile data were collected using a SeaBird SeaCat CTD outfitted with an OBS (turbidity) and oxygen sensor and a Horiba U-10 water quality meter. Profile plots and data are provided in **Appendix G**. In-situ surface water samples were analyzed for temperature, dissolved oxygen, specific conductance, and pH using a Yellow Springs Instrumentation (YSI) meter and Oakton hand-held pH probe. Water transparency was measured using a Secchi disk.

For the purposes of the Massachusetts Water Quality Standards (314 CMR 4.00), Jordan Pond is considered to be a Class B inland waterbody. Class B waters are suitable for: habitat for fish and other wildlife, drinking water supply with appropriate treatment, and agricultural and industrial uses. Class B waters "shall have consistently good aesthetic value."[4]

3.60.1 Temperature

The average temperature in Jordan Pond at the time of sampling on September 26, 2002, was 20.1°C, and only weak thermal stratification was evident from the three water quality profiles collected (see **Appendix G**). The average temperature in the Pond at the time of sampling on October 16, 2002, was 10.0°C. Massachusetts Surface Water Quality Standards for warm water fisheries state that the water temperature should not exceed 28.3°C; this standard was not exceeded by any of the samples collected at Jordan Pond.

Although water quality samples collected as part of this study were insufficient to determine seasonal variations in temperature, it is expected that Jordan Pond experiences a seasonal pattern of stratification and turnover typical of New England lakes and ponds. The profiles that were collected on September 26, 2002, indicate weak stratification, which is expected during the fall turnover period, when wind action acting on the pond typically causes destratification and mixing throughout the entire water column.

3.60.2 Dissolved Oxygen

Dissolved oxygen (DO) in Jordan Pond on September 26, 2002, ranged from 3.5 to 5.8 mg/L at various depths and locations within the Pond, with slightly lower DO concentrations at greater depth for each sampling location. Dissolved oxygen (DO) in the Pond on October 16, 2002, ranged from 7.5 to 10.8 mg/L near the water surface. These

[4] Massachusetts Surface Water Quality Standards, 314 CMR 4.05(3)(b), May 2000.

high levels were likely the result of the inflow of saturated stormwater during testing. DO values greater than 5.0 mg/L are desirable for aquatic life, and DO values below 1.5 mg/L can often result in marked increases in the release of phosphorus from the pond benthic sediments. The Massachusetts Surface Water Quality Standard minimum DO for Class B waterbodies is 5.0 mg/L. Levels of DO across the depth profile of the Pond can be influenced by thermal stratification. During the summer months, it would be expected that the DO levels would be higher towards the surface and lower towards the bottom of the Pond.

3.60.3 pH

The pH levels in the Pond on the two sampling dates ranged from 6.2 to 7.0 Standard Units (SU). The Massachusetts Surface Water Quality Standard range is 6.5 to 8.3 SU. pH plays an important role in pond chemistry, as it can control metal solubility and ammonia toxicity.

3.60.4 Specific Conductance

Specific conductance in Jordan Pond on September 26, 2002, and October 16, 2002, ranged from 200 to 570 μS/cm. Specific conductance is a measure of the amount of dissolved solids present in the water, and values in this range are indicative of moderate to elevated levels of dissolved solids.

3.60.5 Water Clarity and Turbidity

The Secchi disk depth is a simple visual measure of water clarity obtained by lowering a patterned plastic disk into the water column until it is no longer visible. The Secchi depths at Jordan Pond during the two rounds of sampling were all less than 1 meter (3.3 feet), indicative of eutrophic conditions. Algal biomass and suspended sediments are the primary factors which adversely affect water clarity. Poor water clarity is aesthetically objectionable and potentially unsafe for swimmers, therefore Massachusetts State Law prohibits contact recreation when Secchi depths are less than 1.22 meters (4 feet). Water clarity in Jordan Pond is expected to be at its worst during peak algal blooms, which most likely occur in the summer.

Turbidity is a measure of water's ability to scatter light rays, and is commonly used as a simple, inexpensive standard of measurement to estimate water clarity. Turbidity values in shallow water samples at Jordan Pond during the two sampling rounds ranged from approximately 1 to 20 NTU, with values for the bottom water samples ranging from approximately 40 to 130 NTU. Massachusetts Surface Water Quality standards for turbidity dictate that "waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class [B]." Jordan Pond would appear not to meet this standard.

3.60.6 Biochemical Oxygen Demand

Biochemical Oxygen Demand in five days (BOD5) is a measure of the amount of oxygen consumed by aquatic life and decomposing organic material over a five-day period. BOD5 values at Jordan Pond ranged from 12 to 22 mg/L, indicative of a high rate of oxygen depletion. Massachusetts does not currently have a surface water quality standard for BOD.

3.60.7 Waterborne Pathogens

Waterborne pathogens are responsible for the spread of many contagious diseases, but it is technically very difficult and costly to measure pathogen concentrations directly. Common waterborne pathogens include: bacteria, viruses, protozoa, helminths, and algae. It is accepted practice to measure the presence of indicator organisms whose presence and concentrations are likely to be representative of those exhibited by pathogens. For the Jordan Pond Restoration Study, GZA tested water samples for the Fecal Coliform (FC), Fecal Streptococcus (FS), Enterococcus, and *Escherichia coli* (E. coli) bacteria. FC values ranged from 2 to 30 colonies/100 mL for the Pond. As a rule-of-thumb, Total Coliform values are typically five to ten times FC values. FS values at Jordan Pond ranged from 5 to 450 colonies/100 mL. Enterococcus values at Jordan Pond ranged from 140 to 460 colonies/100 mL , and E. coli values ranged from less than 5 to 20 colonies/100 mL. According to Massachusetts State Sanitary Code for freshwater swimming beaches (amended in 2001), no single Enterococcus value shall exceed 61 colonies/100 mL, and the geometric mean of the five most recent samples shall not exceed 33 colonies/100 mL. Also, E. coli values shall not exceed 235 colonies/100 mL, and the geometric mean of the five most recent samples shall not exceed 126 colonies/100 mL. The new Enterococcus/ E. coli-based Massachusetts standard is believed to be more representative of waterborne pathogen concentrations than the old TC/ FC-based standard. Based on the Enterococcus testing results, Jordan Pond would not have met state standards for swimming during the sample collection period. Massachusetts Surface Water Quality standards for secondary contact recreation (e.g.: boating, fishing) for Class B waterbodies dictate that fecal coliform concentrations should not exceed 1000 colonies/100 mL; at the time of sampling, Jordan Pond appeared to meet this standard.

The average FC:FS ratio from the data collected at Jordan Pond was less than 1, which is an indicator that the bacterial contamination is most likely of animal origin, *not* human origin. FC:FS ratios of greater than 4 are indicative of human origin.

3.60.8 Nutrients

Nitrogen was measured at Jordan Pond in multiple forms: nitrate and ammonia, which are the two most biologically accessible forms for plant uptake, and Total Kjeldahl Nitrogen (TKN), the sum of organic nitrogen (unavailable) and ammonia. Nitrogen is an important water quality parameter to assess because it is a key nutrient for aquatic plant growth. Ammonia concentrations at Jordan Pond ranged from 0.2 to 0.3 mg/L, nitrate concentrations ranged from non-detect to 0.01 mg/L, and TKN concentrations ranged from 1.3 to 1.7 mg/L. These values are considered low to moderate, and are within the typical range for New England lakes and ponds. There is currently no quantitative state standard for nutrient levels in surface water bodies.

Both total phosphorus (TP) and dissolved phosphorus were measured at Jordan Pond as part of the current study; TP is the sum of organic and inorganic phosphorus, while dissolved phosphorus is a measure of the most biologically-available form of phosphorus. Along with nitrogen, phosphorus is a key nutrient for aquatic plant growth, and is commonly the limiting nutrient in New England freshwater lakes and ponds, meaning it is the least abundant nutrient and typically controls primary productivity. TP concentrations at Jordan Pond ranged from 0.07 to 0.08 mg/L, while dissolved phosphorus concentrations ranged from 0.06 to 0.08 mg/L. The average TP for eastern and central Massachusetts lakes and ponds is approximately 0.014 mg/L. From this limited data, it is apparent that phosphorus concentrations in Jordan Pond are very high and a large proportion of the phosphorus is available for plant uptake.

The nitrogen-to-phosphorus ratio from these data is approximately 20:1; this ratio is important in determining the limiting nutrient in a water body. Plant stoichiometry dictates a minimum N:P ratio for plant growth of 7.2:1, while a N:P ratio of 15:1 or greater is typically indicative of phosphorus limitation.

3.60.9 Trophic State

The trophic state index (TSI) of a water body is a convenient tool to estimate the productivity of a lake or pond with limited available data. The most commonly used TSI was developed by Carlson (1977), and is a function of Secchi depth, Chlorophyll a, and/or TP. Note that Carlson's TSI was developed for lakes with few rooted plants and little non-algal turbidity, and for use with summer data; thus, its value for use at Jordan Pond is limited. Carlson's TSI equations for Secchi depth and TP are as follows:

$$\text{TSI} = 60 - 14.41 * \ln(\text{Secchi Depth, m})$$
$$\text{TSI} = 14.42 * \ln(\text{Total Phosphorus, } \mu\text{g/L}) + 4.15$$

Using TP and Secchi depth data, the average TSI for Jordan Pond was 70. A TSI less than 40 is considered oligotrophic (nutrient-poor), 40 to 50 is mesotrophic (moderate nutrient content), and greater than 50 is eutrophic (nutrient-rich).

Similarly, the trophic state of a pond can be evaluated based on direct relationships to TP concentrations or Secchi depth. TP concentrations of less than 0.01 mg/L are considered oligotrophic; 0.01 to 0.02 mg/L, mesotrophic; and greater than 0.02 mg/L, eutrophic. Ponds with TP concentrations greater than 0.05 mg/L (such as Jordan Pond), are sometimes sub-classified as hypereutrophic (extremely nutrient-rich). For Secchi depth, greater than 4 meters is considered oligotrophic; 2 to 4 m, mesotrophic; and less than 2 m, eutrophic.

Trophic State	TP (mg/L)	Secchi depth (m)
Oligotrophic	< 0.01	> 4
Mesotrophic	0.01 – 0.02	2-4
Eutrophic	> 0.02	< 2

Based on Carlson's Trophic State Indices and direct relationships to TP concentrations and Secchi depths, Jordan Pond is considered to be a eutrophic (to hypereutrophic) water body. This means it has been very impacted by nutrient inputs and has conditions very favorable to abundant plant and algae growth.

3.70 WATERSHED SAMPLING DATA

On October 16, 2002, GZA sampled the discharge from the two 30-inch concrete stormwater drainage pipes located at the northern bank of the Pond. Sample SWO-1 was collected at the northern outfall (with concrete headwall located immediately adjacent to Lakewood Drive), and sample SWO-2 was collected at the northwestern outfall (located in the Jordan Pond Park, near the pump station). The total rainfall for the storm which occurred on October 16, 2002, as measured at the Worcester airport weather station, was 0.95 inches, while the maximum 1-hour precipitation for the storm was 0.12 inches. The storm began early in the morning of the 16^{th}, and GZA sampled the discharge at approximately 1:30 PM. The data collected in presented in **Table 3-2**.

Flow in the northern and northwestern stormwater outfall pipes at the time of sampling was measured to be approximately 250 and 450 gallons per minute, respectively. DO concentrations in the northern and northwestern stormwater outfall pipes were 10.5 and 10.8 mg/L, respectively, which are typical due to the aeration of free-flowing water. The temperature of the stormwater was approximately 20°C, and the pH was approximately 7.0 standard units. The turbidity at SWO-1 was 24 NTU. The fecal coliform count at SWO-1 was 2900 colonies/100 mL. The fecal streptococcus count at SWO-1 and SWO-2 was 8000 and 5600 colonies/100 mL, respectively. At SWO-1, the nitrate concentration was less than 0.01 mg/L, the ammonia concentration was 0.2 mg/L, and the TKN concentration was 1.0 mg/L. Also, the total phosphorus concentration was 0.19 mg/L and the dissolved phosphorus concentration was 0.12 mg/L. These values are typical of urban runoff, as compared to the results of the National Urban Runoff Program (NURP).

The discharge from the northern outfall pipe reportedly appears "soapy" from time to time; there are two likely explanations for this appearance. First, isolated activities occurring within the watershed, such as the washing of cars, dumpsters, or shopping carts, may result in soapy water being discharged into stormwater catch basins. Second, bubbles resulting from the presence of natural humic acids in the discharge may give the impression of soapy discharge. The Town of Shrewsbury Board of Health has tested for the presence of MBAS (a surfactant) in the past, with limited success. Because of the physical nature of surfactants and the likely frequency of their discharge in the Jordan Pond watershed, it would be difficult, in GZA's opinion, to obtain representative stormwater samples with which to quantify their impact on Jordan Pond.

3.80 SEDIMENT DATA

On November 14, 2002, CR, under subcontract agreement to and supervision of GZA, collected several sediment samples from the bottom of Jordan Pond in order to characterize the sediment materials and judge their suitability for dredging. Locations of sediment sampling are shown on **Figure 3-12**. Surface sediment samples were collected using a Petite Ponar dredge. Sediment at each of the three sample stations consisted of fine dark brown organic silt with a trace of senescent vegetation. The apparent remains of the autumn blue-green algae (*Oscillatoria*) bloom were present at the surface of each grab. An oxic layer of sediment about 1 to 2 mm thick was present in each grab. The dominant visible macroinvertebrates in surficial sediments were Chironomids (midge larvae).

The results of the sediment laboratory analyses are presented in **Table 3-3**, the laboratory reports are attached as **Appendix F**, and relevant supporting data is attached as **Appendix G**. In general, the sediment analyses indicate that the sediment within Jordan Pond consists primarily of silty fine sand and organic material, and is rich in phosphorus. These samples were found to have somewhat elevated levels of lead, arsenic, and Total Petroleum Hydrocarbons (TPH). Besides these three parameters, the sediment was not found to have any other elevated levels of metals, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAH), or polychlorinated biphenyls (PCBs). Currently, the sediments do not pose an ecological risk within the Pond. The Massachusetts Contingency Plan (MCP) Reportable Concentration thresholds do not apply to in-place sediments. The sediment samples have an average organic content of 17 percent and average 14 percent solids; these values are in the typical range of New England lake and pond sediments and indicate a significant amount of decaying organic matter.

The TP concentrations in the sediment ranged from 1200 to 1700 mg/kg, which is considered high. The TP in the sediment is likely due to decaying organic matter, and likely represents a significant source of phosphorus to the water column via internal recycling mechanisms. Refer to Section 5.10 for a further discussion regarding sediment phosphorus loading. Note that the available phosphorus fraction is accepted to be a more reliable indicator of available sediment phosphorus than TP, but requires a much more involved testing procedure.

The arsenic concentration in the composite sediment sample from Jordan Pond was 36.5 mg/kg. For comparison, the MCP Reportable Concentration for both Soil Type 1 (RCS-1) and Soil Type 2 (RCS-2) for arsenic is 30 mg/kg. The average arsenic concentration in Massachusetts lakes and ponds is 17.1 mg/kg, with a likely range of 0 to 104 mg/kg. Arsenic is found in stormwater runoff from roadways, from agricultural pesticides, and in ponds that have historically been treated with sodium arsenate herbicide. Arsenic occurs in Massachusetts in background levels of approximately 10 mg/kg, but some parts of central Massachusetts have elevated natural levels of arsenic as a result of the local geology.

The lead concentration in the composite sediment sample from Jordan Pond was 454 mg/kg. For comparison, the MCP RCS-1 for lead is 300 mg/kg and RCS-2 is 600 mg/kg.

The average lead concentration in Massachusetts lakes and ponds is 203 mg/kg, with a likely range of 3 to 950 mg/kg. Lead is found in stormwater runoff from roadways, and occurs in Massachusetts in background levels of 10 to 30 mg/kg.

The TPH concentration in the composite sediment sample from Jordan Pond was 1500 mg/kg. For comparison, the MCP RCS-1 for TPH is 200 mg/kg and RCS-2 is 2000 mg/kg. TPH is found in stormwater runoff from roadways and in all petroleum products.

4.00 AQUATIC VEGETATION & BIOLOGICAL SURVEY

4.10 AQUATIC VEGETATION SURVEY

On November 14, 2002, CR, under subcontract agreement to and supervision of GZA, performed an aquatic vegetation survey of Jordan Pond. The purpose of the survey was to identify the dominant plant species present in the Pond and categorize their distribution and density. Surveying was performed from a boat by a CR aquatic biologist using GPS instrumentation to record locations. **Figure 4-1** is a map showing the estimated thickness of senescent[5] aquatic vegetation, and **Figure 4-2** is a map showing aquatic plant coverage Jordan Pond. As shown in **Figure 4-2**, the Pond exhibited essentially 100 percent coverage of Elodea and Bluegreen Algae. Note that differences in vegetative cover result in the time of year when data was collected.

The dominant species of aquatic vegetation present at Jordan Pond were:

Common Name	Latin Name
Waterweed	*Elodea nuttallii*
Bluegreen Algae	Cyanophyte: *Oscillatoria*
Broad-leaved Cattail	*Typha latifolia*
Pondweed	*Potomogeton* sp.
Yellow Water Lily	*Nuphar* sp.

Elodea nuttallii is native and one of three species of Elodea found in the United States, and is also known as Western Waterweed or Nuttall's Waterweed. *Elodea nuttallii* is very similar to the more common Canadian Waterweed, *Elodea Canadensis*. *Elodea nuttallii* is not considered an invasive plant in Massachusetts; however, it can be confused with *Hydrilla verticallata*, which is considered to be an invasive species. Elodea is a perennial submersed aquatic plant, rooted or drifting free when broken loose, very brittle, and fragmenting easily. The leaves are pale green, typically in whorls of 3 and occasionally 4, and are arranged on a slender, freely branched, stem, 12 to 40 inches in length with a round cross section. The plants grow in lakes, ponds and in slow moving water in rivers, canals and streams. They are sometimes found in slightly brackish coastal waters. Elodea plants die back in autumn, and spring regrowth is from under-sediment stems crowned by roots or

[5] The final growth phase of a plant (or plant part), from full maturity to death.

winter buds. Dense populations of plants reduce the dissolved oxygen concentrations. (APIS 2001).

The Cyanophyte *Oscillatoria* is a mat forming, prokaryotic, Bluegreen algae that consists of long, unbranched filaments. *Oscillatoria* often begin growing on the sediment surface, and rise in the water column due to trapped oxygen.

As discussed in Section 3.60.8 – Nutrients, phosphorus is likely the limiting nutrient in Jordan Pond. At the time of survey, however, Jordan Pond had nearly 100 percent coverage of aquatic vegetation. Thus, the available nutrients in Jordan Pond *do not appear to limit* the growth of aquatic vegetation in the Pond. Rather, the growth of aquatic vegetation is limited by the physical constraint of the pond area. Even though neither nitrogen nor phosphorus is likely the limiting factor in Jordan Pond, management plans should focus on phosphorus loading, as enough of a reduction in phosphorus loads will likely result in phosphorus becoming the limiting factor in aquatic plant growth.

4.20 BIOLOGICAL SURVEY

On September 26, 2002, and October 16, 2002, a GZA scientist performed a brief biological survey of Jordan Pond and the immediately adjacent shoreline using non-invasive techniques. GZA either observed directly or observed signs of the following animals while on-site:

Common Name	Latin Name
Canada Geese	*Branta canadensis*
Mute Swan	*Cygnus olor*
Wood Duck	*Aix sponsa*
Mallard	*Anas platyrhynchos*
Blue-winged Teal	*Anas discors*
American Crow	*Corvus brachyrhynchos*
Painted Turtle	*Chrysemys picta*
Green Frog	*Rana clamitans*
Muskrat	*Ondatra zibethicus*
Eastern Garter Snake	*Thamnophis sirtalis*
Eastern Chipmunk	*Tamais striatus*
Gray Squirrel	*Sciurus carolinensis*
Raccoon	*Procyon lotor*
White-tailed Deer	Odocoileus virginianus

A formal fish survey was outside of the scope of work for this project. However, anecdotal and historic evidence suggest that the following species of fish now or formerly inhabit Jordan Pond:

Common Name	Latin Name
Bluegills	*Lepomis gibbosus*
Largmouth Bass	*Micropterus salmoides*
Brown Bullheads	*Ameirurus sp.*
Yellow Perch	*Perca flavescens*
White Perch	*Morone americana*
Golden Shiners	*Notemigonus crysoleucas*
Rainbow Trout	*Oncorhynchus mykiss*
Brook Trout	*Salvelinus fontinalis*

This species list incorporates Rainbow Trout and Book Trout, which are both stocked annually in Jordan Pond by Mass Wildlife. Approximately 1,000 fish are stocked each spring, and it is reported that there is no annual carryover of this population, likely a result of the elevated water temperature, low dissolved oxygen levels, predation, and fishing.

5.00 NUTRIENT AND BACTERIA LOADING

5.10 NUTRIENT LOADING

GZA developed a customized, land-use based watershed nutrient loading model for Jordan Pond using the Generalized Watershed Loading Function (GWLF) model developed by Haith, Mandel and Wu (v.2, 1992). GWLF is a continuous simulation model which uses a daily time step for weather data and water balance calculations. GZA calibrated the model to a limited amount of actual data, in conjunction with the results and methodology from the Jordan Pond TMDL study, set forth in the Massachusetts DEP's *Draft Total Maximum Daily Loads (TMDLs) of Phosphorus for Selected Northern Blackstone Lakes.* Results and supporting documentation for the models are included as **Appendix H**. Note that, given the extremely limited amount of nutrient data available for Jordan Pond, the models described here are most useful as diagnostic tools to evaluate the relative impacts of various management options, rather than for absolute replications of precise conditions within the watershed and Pond.

5.10.1 Nitrogen Budget

Nutrient budgets for nitrogen and phosphorus for Jordan Pond were calculated, and a summary of the results is contained in **Table 5-1**. The total nitrogen load for Jordan Pond was estimated to be approximately 546 kg/yr. Of this load, approximately 26 kg/yr (5 percent) are a result of direct atmospheric deposition, 17 kg/yr are a result of waterfowl (3 percent), and 503 kg/yr (92 percent) are a result of watershed loading. Approximately two-thirds of the nitrogen loading from the watershed is a result of residential land uses, which corresponds to 60 percent of the total nitrogen loading to the Pond.

5.10.2 Phosphorus Budget

The total load for phosphorus for Jordan Pond was estimated to be approximately 108 kg/yr, which is comprised of about 5 kg/yr (5 percent) each from waterfowl and direct atmospheric loading. Watershed sources account for 97 kg/yr of phosphorus (90 percent), with residential properties contributing 80 percent of the watershed loading, or 72 percent of the total load.

5.10.3 Nutrient Loading Sources

Atmospheric deposition of nutrients was estimated using empirical equations, and can occur as both wet (rain and snow) and dry (fallout of particles) precipitation. Atmospheric loading accounted for less than 5 percent of the total load to Jordan Pond for both nitrogen and phosphorus, and can not be reduced or minimized by any watershed management options.

Direct nutrient loading by waterfowl also accounted for less than 5 percent of the total nutrient load to the Pond. The nutrient load from waterfowl is contributed to the Pond in the form of waste. From a nutrient loading perspective, waterfowl management is likely to have a minimal impact on water quality. When developing this estimate, waterfowl populations and nutrient loading rates were assumed based on engineering judgement and published literature.

Nutrient loading from residential properties occurs in multiple forms, primarily through pet wastes (both on the street and in the yard) and fertilizers applied to lawns and gardens. Residential nutrient loading is greatly increased by the presence of on-site septic systems. Improperly functioning septic systems are particular culprits, though these have been largely repaired in the Jordan Pond watershed. Residential, non-point source nutrient loading reductions must primarily be achived through behavioral modifications of the part of the watershed residents; refer to Section 8.1 for more details.

5.10.4 Impacts of Nutrient Loading

Given the relatively small size of the watershed and Pond, the estimated nutrient loads to Jordan Pond are quite large. The results of the GWLF watershed loading model were incorporated into an in-pond phosphorus model developed by Chapra (1997). As with the watershed model, the assumptions that go into developing the in-lake model are significant, and the results are most useful as a tool to assess the relative impact of watershed development on water quality in Jordan Pond. The modeled in-lake total phosphorus concentration is expected to be approximately 0.08 mg/L. Note that the in-pond total phosphorus concentrations measured as part of this study ranged from 0.07 to 0.08 mg/L; phosphorus concentrations in this range indicate eutrophic to hypereutrophic conditions.

For comparison purposes, GZA modeled the nutrient loading from the Jordan Pond watershed under “pre-developed” conditions (i.e.: 100 percent forested). The relevant model documentation can be found in **Appendix H**. Under forested watershed conditions, it is estimated that the watershed nutrient load is approximately 115 kg/yr of nitrogen and 6 kg/yr of phosphorus. Factoring the direct loading sources (atmospheric loading and waterfowl), the total nitrogen and phosphorus loads are approximately 158 kg/yr and 16 kg/yr, respectively. The corresponding in-lake total phosphorus concentration is expected to be approximately 0.01 mg/L. Thus, under "baseline," pre-developed conditions, the trophic state of Jordan Pond is expected to be on the border between oligotrophic and mesotrophic. From the results of this pre-development analysis, it is evident that watershed development has had a significant impact on nutrient loading to Jordan Pond, and, subsequently, to the quality of water and trophic state within the Pond.

The models described above account for external nutrient loading to Jordan Pond, such as from the watershed and waterfowl. However, it is likely that there is a signficant source of phosphorus within the Pond itself: sediment. The impact of pond sediment on nutrient loading is difficult to quantify; the release of phosphorus from pond sediment is governed primarily by the dissolved oxygen levels in the hypolimnion, but additional factors include the fraction of available phosphorus in the sediment and the presence and concentrations of dissolved metals (especially iron) in the sediment. Generally, it is assumed that phosphorus is no longer bound in the sediment when hypolimnetic DO levels drop below 1.5 mg/L, and thus begins to become resuspended in the water column. Agitation of the pond sediment can also release phosphorus. Common sources of sediment agitation include: swimmers; bottom feeding fish; and wind, wave, and motorboat action in shallow waters.

Given the high concentrations of phosphorus within the sediment samples tested as part of this study, in conjunction with the low hypolimnetic dissolved oxygen levels which are presumed to occur at Jordan Pond in the summer, internal sediment phosphorus loading is likely a major source of phosphorus loading to Jordan Pond, in GZA's opinion.

5.20 BACTERIA LOADING

GZA developed a simple, quantitative evaluation of bacteria loading for Jordan Pond based on estimated inputs from the various sources known and assumed to be contributing load to the Pond. These include surface water runoff, septic systems, and direct input from waterfowl (ducks and geese). Formal counts were not conducted for waterfowl, nor was a survey undertaken to determine the population of dogs and other animals within the watershed. Thus, GZA made assumptions regarding the contributing populations of dogs, ducks, and geese. Septic systems were not included as a source of bacterial loading to Jordan Pond since septic systems in the Jordan Pond watershed have been largely repaired or replaced recently by sewer systems. The bacteria data collected as part of this study indicate that faulty sewer lines and septic systems are likely not a major source of bacteria contamination, as the fecal coliform to fecal streptococcus ratios calculated from the data indicate that the source of bacterial contamination in the Pond is non-human in origin. A simple bacterial decay rate was developed based upon water quality data collected at Jordan Pond, in concert with published information.

It is estimated that $10x10^{13}$ colonies of fecal coliform bacteria enter Jordan Pond per year, yielding an annual average inflow concentration of approximately 23,000 colonies/100 mL per year. The fecal coliform loading is largely from ducks (64 percent), followed by dogs (30 percent) and geese (6 percent). For comparison, the measured fecal coliform concentrations at SWO-1 and SWO-2 during the "wet weather" sampling on October 16, 2002, were 2,900 colonies/100 mL and 5,600 colonies/ 100 mL, respectively. Assuming a bacterial loss rate of 1.90 per day, the average in-pond fecal coliform bacteria concentration is expected to be 77 colonies/100 mL. For comparison, the measured concentration on October 16, 2002, was 26 colonies/100 mL.

The actions already taken by the Town to address failing septic systems and to convert residences served by septic systems to sewer service are important steps in addressing bacterial contamination in Jordan Pond. Waste generated by waterfowl and dogs is a significant contributor of bacteria and waterborne pathogens to Jordan Pond. To attempt to meet the state health code for contact recreation for bacteria, it would be necessary to take steps to reduce the impact of waterfowl and to encourage watershed residents to clean up after their pets.

6.00 WATERFOWL

6.10 WATERFOWL IMPACTS

A moderate waterfowl population can be an aesthetically pleasing aspect of a healthy pond environment. However, an excessively large or domesticated waterfowl population can have serious implications for water quality, aesthetics, and public health and safety. As discussed in Section 5.00, Nutrient and Bacteria Loading, waterfowl can be an significant source of pathogens, bacteria, and nutrients to a water body. At Jordan Pond, waterfowl are a major source of bacteria and pathogens, but a minor source of nutrients. In addition, numerous studies have shown that human-waterfowl interactions can be deleterious to both humans and waterfowl.

Based on GZA's limited observations made during the course of this study, the extent of the waterfowl population at Jordan Pond includes 16 ducks, 7 resident geese, and 2000 goose-days of migratory geese (e.g. 1000 geese present for 2 days), for a total of 5840 duck-days and 4555 goose-days. The exact number of migratory geese and the average duration of stay for migratory geese at Jordan Pond were not determined.

6.20 WATERFOWL MANAGEMENT OPTIONS

GZA has researched and assessed methodologies for preventing waterfowl from congregating on the shoreline and in the Pond. In general there are three broad categories of wildlife control methods 1) Harassment and Hazing, 2) Environmental Alteration, and 3) Population Control. In providing our waterfowl management recommendations, GZA has focused on methods that are not labor intensive (since the Town is unlikely to be able to dedicate significant staff resources to this task) and which will be acceptable to local residents (e.g.: discharging firearms is unlikely to be appropriate given the location of the Pond). Typically, a variety of methods are needed since the birds will quickly adapt to a single tactic. The most commonly practiced methods of Canada goose population controls are discussed below.

<u>Harassment and Hazing</u>

Visual Deterrents

Reflective tape and Mylar flagging have had mixed results for repelling waterfowl from crops or other habitat areas. Generally, while effective for a short period of time, the long-term effect is negligible.

Scarecrows have had mixed results as a waterfowl control measure. Effigies are available in the shapes of humans, swans, and dead geese. In general, scarecrows are most effective when they are moved frequently and alternated with other methods. They tend to lose effectiveness over time and as goose populations increase. Geese in urban and suburban areas are not likely to be frightened by scarecrows due to their nearly constant contact with people.

Distress Calls

Recordings of goose distress calls have been used to try to frighten geese away from an area. While temporarily effective, the geese resettle when the goose calls end. Also, the volume required to make these effective in an urban or suburban area may violate local noise ordinances and may be objectionable to the residents; thus, distress calls are not likely to be appropriate for Jordan Pond.

Pyrotechnics

Screamer shells, bird bombs, and 12-gauge cracker shells have been shown to repel many species of birds. Screamer shells have specifically been found to repel Canada geese. Flocks in urban areas sometimes require continuous harassment with frequent discharges of pyrotechnics, as geese return within hours of cessation. It has been found that efficacy of harassment is partially based on the availability of other feeding grounds for the geese. Geese repelled using pyrotechnics will move to other local areas with appropriate habitat. Pyrotechnics are loud and potentially dangerous. The noise can annoy people and trigger dogs to bark incessantly. They are potential fire hazards and legal implications must be examined. Pyrotechnics are not likely to be appropriate for Jordan Pond.

Trained Goose Dog

Specially trained border collies are able to haze geese until they leave the area. Some companies will supply and work the dog for the time needed, while others will sell the collie outright. Research shows that the goose dogs have the greatest effect when the body of water patrolled is less than two acres in size. When harassment stops, goose populations tend to return to pre-treatment numbers. In addition to the up-front costs, annual upkeep of the goose dog and salary of a handler must be budgeted. Alternatively, local residents with suitable dogs can be enlisted in the goose harassment area. If volunteers are available, the dogs and owners could be trained and outfitted to provide some level of hazing during the course of normal daily exercise.

<u>Environment Alteration</u>

Chemical Repellants

Some research has shown methyl anthranilate applied to the turf may be effective in the short term (around four days), but results do vary. Specifically formulated goose repellants are available commercially. Frequent reapplication is necessary because the chemical is water soluble and also must be reapplied after lawn mowing.

Modify Landscaping

Since geese prefer tundra-like habitat, modifications can be made to make vegetation unpleasant to them. Groundcovers such as common periwinkle (*Vinca minor*), English ivy (*Hedera helix*) and Japanese pachysandra (*Pachysandra terminalis*) all are objectionable to geese. This method works best if there are alternative feeding sites nearby.

Barrier Installation

Barriers include fences, hedges, shrubs, and boulders set at the edge of the land. They can be temporary or long-term, but geese are likely to rediscover a habitat if barriers are removed. Geese prefer to land in the water and walk onto shore to eat and nest. Barriers prevent them from doing so, reducing their comfort level in an area.

<u>Population Control</u>

Removal of Domestic Waterfowl

Flocks of urban waterfowl are known to attract over-flying migrating waterfowl. Birds learn to locate food resources by watching the behavior of other birds. Removing the full-time resident geese can reduce the number of migratory geese that will come to an area.

Hunting

Hunting can be used to reduce goose populations. Local and state laws regulate waterfowl hunting. Given the urban nature of Jordan Pond, hunting is an inappropriate waterfowl management technique in this case.

Egg Destruction

There are several ways to destroy Canada goose eggs that prevent future populations from growing. Addling, oiling, freezing, replacement, and puncturing of eggs reduce gosling production, but not as efficiently as removing immature or breeding adults. Approximately five eggs must be made unviable to prevent one adult from joining the breeding population.

Contraception

There are no contraceptive drugs registered with the FDA for Canada geese. Vasectomization has been used to reduce gosling production, but is only effective if the female does not form a bond with another male. Also, since a Canada goose's average lifespan is more than 20 years, the current overabundance of geese would not be alleviated in a reasonable time.

Relocation

Relocation of Canada geese has been attempted, with mixed results. While juvenile geese respond well to relocation, over half of adult geese return to their original homes. Relocation of Canada geese also has the potential to spread disease.

6.30 WATERFOWL CONTROL RECOMMENDATIONS

Based on the results of GZA's bacteria modeling, waterfowl are a significant source of bacteria at Jordan Pond. To consistently meet state swimming regulations, GZA believes that it is necessary to control the resident waterfowl population using harassment methods. However, as it is the desire of the Town of Shrewsbury to restore Jordan Pond for reasons that do not include swimming, GZA recommends that the resident waterfowl population be controlled by habitat alteration, such as by reconfiguring the beach landscaping.

Many of the previously described control methods have been found to be ineffective in suburban and urban environments because of geese's almost constant contact with humans, traffic, and noise. Other methods require a large expenditure of funds, or recurring labor and product expenses. Still others, such as the noisemaking options, would be a nuisance to the residents around Jordan Pond.

Although the resident goose population at Jordan Pond is relatively small in size, there is an added benefit of controlling the resident population as they relate to the much larger migratory population. During the course of migration, it is believed that migrating geese evaluate potential resting and foraging “pit stops” by the presence and size of a resident goose population (i.e.: “if the pond is okay for them, then it’s okay for us”). Conversely, migratory birds are less likely to visit Jordan Pond if it seems inhospitable, based on a lack of a resident goose population. Thus, controlling the small resident population has the potential of controlling the migratory populations of hundreds of geese.

The methods of goose control most accommodating to the Town’s requirements are those that change the environment so as to be unfriendly to goose populations. Altering landscaping is a one-time expense that will reduce habitat for the resident geese. Geese prefer large, relatively flat areas with short grass and other low vegetation adjacent to open water. Young grass shoots with fine blades, such as Kentucky bluegrass, are preferred food for geese. Removing such grass and replanting with vegetation such as pachysandra and periwinkle reduces the foraging ability of the geese in an area, although most plants that grow quickly, dense, and at least 10-inches tall are viable alternatives. Geese are also uncomfortable where sightlines are limited, as this condition impedes their ability to react quickly to predators. Planting meadow vegetation and low shrubs on the shore can maintain visual access for human residents while decreasing the ability of geese to forage on the shore and reducing their comfort level.

Geese typically land on the water and walk up onto shore to forage or nest. Creating a barrier between the water and land both reduces their sightline and impedes their natural movement. This can be done in an aesthetically pleasing manner with fences or boulders. These obstructions should be located so that straight-line movement is not possible, as this interferes with the goose’s escape paths.

7.00 INFLOW / OUTFLOW AUGMENTATION

7.10 JORDAN POND WATER BUDGET

GZA performed simple hydrologic and hydraulic analyses of Jordan Pond to evaluate the relative impact of various Pond inflows and outflows on water quality in the Pond, and also to evaluate the impact flow augmentation as a potential management option.

Inflows to Jordan Pond include: baseflow (a.k.a. groundwater), runoff, and direct precipitation. Outflows from the Pond include: streamflow (consisting of baseflow and surface water flow) and direct lake evaporation. There are no direct discharges to or withdrawals from the Pond, and the Pond is not used as a public water supply.

GZA developed a simple annual water budget model for Jordan Pond, based upon climate and land use data for the years 1997 through 2001. See **Table 7-1** for a summary of the water budget results. Based on the results of this model, average inputs to the Pond total approximately 139.2 million gallons per year (Mgal/yr) (245 inches/year). Baseflow, runoff, and direct precipitation constitute 51 percent, 33 percent, and 16 percent of the inputs, respectively. Direct lake evaporation, calculated using the Thornthwaite equation, was estimated to be 14.8 Mgal/yr (26 in/yr). Since there are no direct withdrawals or other output sources, it was assumed that streamflow out of Jordan Pond comprises the remainder of the outflows from the Pond. Streamflow from the Pond, consisting of surface water and groundwater flow, is estimated to be 124.4 Mgal/yr (219 in/yr). The breakdown of surface versus subsurface flow was not calculated, as this is beyond the scope of this study.

7.20 OUTLET CHANNEL

A surface discharge channel was observed at the western shoreline of Jordan Pond. Based on visual observation, the ill-defined channel invert appears to be at the crossing of the walking trail and sewer line. The sewer line along the west edge of the Pond was installed in 1966-1967, and raised the outlet channel invert considerably. According to observations made by the Town and local residents, this construction significantly altered the hydrologic conditions of the Pond outlet, as the channel used to flow freely under normal conditions, and now flows less frequently as surface water outflow. Previous to the sewer line construction, the outflow from Jordan Pond was controlled by a formal sluiceway outlet structure, likely owned and operated by a nearby icehouse operation. The foundation of the icehouse is still visible near the outlet channel.

Based on GZA's site observations made during the course of this study, the outlet channel is approximately 10 feet wide and 2 feet deep, with a sand and gravel bed. Refer to **Figure 3-2** for an orthophotograph showing the outlet channel. At the time of observation, the channel contained a variety of debris, including: tree branches, loose stones, and some shrubbery. The discharge channel appears to be well established, indicating routine flow. There are remnants of an approximately 18-inch tall fieldstone wall along the right bank of the channel, upstream of Roberts Street, and a concrete culvert, approximately 4 feet wide by 3 feet tall, under Roberts Street. Downstream of Roberts Street, the channel is approximately 8 feet wide and 1 foot deep. There is a stone masonry headwall and a 4-foot wide by 3-foot tall concrete box culvert located at South Quinsigamond Avenue which both appear to be in excellent condition. Downstream of South Quinsigamond Avenue, the outlet channel is contained within a subsurface box culvert which flows alongside Brookside Place and which eventually discharges to Lake Quinsigamond.

7.30 FLOW AUGMENTATION CONSIDERATIONS

Increasing the outflow from the Pond could assist with flushing nutrients out of the Pond and improving water quality, such as decreased water temperature and increased dissolved oxygen. There are two key issues which GZA addressed in considering this task: 1) How to physically discharge water from the Pond, and 2) How to replace the water so as to maintain the Pond level.

Conceptually, there are two options for increasing flow through the pond: lowering the outlet to the pond to increase flow-through of groundwater, or introducing a source of clean surface water. Lowering the outlet of the pond below typical groundwater table elevations in the surrounding landscape may promote groundwater discharge to the pond. However, this may be limited by regional hydrologic considerations (the surface of Lake Quinsigamond is only about 3 feet lower than the surface of Jordan Pond), and would require lowering typical water levels in Jordan Pond. Characterizing and quantifying the regional groundwater flow is out of the scope of the current project, but it is possible that Jordan Pond may experience little to no groundwater inflow during the late summer months, especially during periods of drought. The lack of groundwater inflow during dry summer periods would decrease the flushing of Jordan Pond, possibly leading to water stagnation, increasingly hospitable conditions for plant and algal growth, and decreased water quality.

Outflow from the pond is controlled by a shallow channel which has silted in and is clogged with vegetation. Because of the close proximity of the sewer line, restoration of this channel would probably require the construction of a formal control structure. The outlet structure would likely be a concrete sluiceway, with removeable stoplogs for water level control and encasement protection for the newly-exposed sewer pipe. The sewer pipe will likely have to be armored to protect from vandalism, weather effects, and freezing temperatures. The outlet structure would also need to be protected against tampering and vandalism.

There are multiple issues associated with lowering the Pond outlet as a means of increasing outflow:

- Lower water levels in Jordan Pond will likely exacerbate the nuisance aquatic weed problem, and will have a detrimental effect on in-pond water quality (e.g. stagnation, increased water temperature, decreased dissolved oxygen);
- Lower water levels will provide more suitable habitat for waterfowl by exposing new shoreline; and
- Increased outflow will not address the underlying causes of eutrophication in Jordan Pond, namely watershed nutrient loading.

For these reasons, increasing the outflow from Jordan Pond by lowering the outlet channel invert is not recommended by GZA as a stand-alone option for pond restoration. However, increasing the outflow of Jordan Pond may be a useful management approach after further study, and in conjuction with additional measures.

Introducing a source of clean surface water as an input to Jordan Pond is another means to increase flow through the Pond. A potential source of additional surface water to Jordan Pond is the outflow from Old Mill Pond. Old Mill Pond discharges to a stream called Kings Brook. According to the USGS Topographic Map, records at the Shrewsbury Engineering Department, and GZA’s field observations, this brook enters a culvert near the Spag’s parking lot, and flows west, through this culvert, along Route 9, for approximately 3,000 feet, and ultimately discharges directly to Lake Quinsigamond. The inlet to the Kings Brook culvert is approximately six feet higher in elevation than Jordan Pond, and there are no wetland resources between the inlet of the Kings Brook culvert and Lake Quinsigamond. From a techinical and regulatory perspective, such a water diversion seems viable.

The intended effect of increasing the inflow to Jordan Pond is twofold: dilution of contaminated incoming waters, and an increased flushing rate through the Pond. Diverting water from Kings Brook would serve to increase the flushing rate in Jordan Pond, which is desirable for maintaining lower water temperature, increasing dissolved oxygen concentrations, and physically flushing out suspended solids and vegetation.

The problem with diverting water from the Kings Brook culvert to Jordan Pond lies in the quality of the water in Mill Pond, and ultimately the water in Kings Brook. The Massachusetts DEP report, *Draft Total Maximum Daily Loads (TMDLs) of Phosphorus for Selected Northern Blackstone Lakes*, includes Mill Pond in Shrewsbury. The report predicts the in-lake total phosphorus in Mill Pond to be approximately 0.047 mg/L, indicating that Mill Pond is eutrophic; GZA's observations of Mill Pond, conducted on November 14, 2002, appear to confirm this. Thus, should water from Kings Brook be diverted to Jordan Pond, the mass loading of nutrients to Jordan Pond would actually increase significantly, and the water quality in Jordan Pond would suffer as a result. So, although the increased flow of water to Jordan Pond would be beneficial, the introduction of an additional significant source of nutrient loading to the Pond would offset the benefits realized by increased flushing. For this reason, GZA does not recommend diverting water from Kings Brook into Jordan Pond.

Two additional sources of water to Jordan Pond were investigated: pumping water from Lake Quinsigamond and groundwater wells. Obtaining water from the Lake would require pumping against a hydraulic grade, with new facilities and infrastructure needed to do so. The water quality in Lake Quinsigamond is considered to be marginally better than that in Jordan Pond, so benefits would not be significant. The installation of a new groundwater well near Jordan Pond could potentially be a source of relatively clean water. The quantity of water necessary to favorably impact the flow-through hydrology of Jordan Pond is quite large, potentially double the current inflow to the Pond. As a result, the effect on regional hydrology and existing nearby public water supply wells may be considerable, and the permitting requirements to construct such a well (or wells) would be concurrently significant. GZA does not recommend obtaining water from Lake Quinsigamond via pumping or from newly constructed groundwater wells as a pond management option.

8.00 WATERSHED MANAGEMENT OPTIONS

Watershed techniques focus on restoration and long-term protection of Jordan Pond through improvements within the drainage areas, and include mitigation of stormwater impacts and improved management of shoreline areas (i.e. through the implementation of Best Management Practices – BMPs). Watershed management alternatives for the control of point and non-point sources of nutrients and pollutants were evaluated, and subdivided into source controls and transport mitigation.

8.10 SOURCE CONTROLS

Source controls seek to reduce the amount of nutrients and pollutants produced within a watershed, thereby ultimately reducing concentrations in downstream waterbodies.

Zoning and Land Use Regulations

Due to the relatively urbanized, built-out nature of the Jordan Pond watershed, source controls concering zoning, land use regulations, land acquisition, easements, and restrictions may be very difficult to implement for socio-political reasons. Approximately 30 percent of the Jordan Pond watershed is currently forested or open space. The impact of various watershed land uses on in-pond water quality is well-studied and documented, and the underlying conclusion is that developed land typically results in much higher pollutant loads than undeveloped lands. For this reason (among others), it is important to preserve open space and forested land within a watershed, and the Jordan Pond watershed is no exception. In addition to any supplemental watershed and in-pond management options, GZA recommends that the Town of Shrewsbury work to preserve the existing open space within the Jordan Pond watershed and prevent new development within these currently undeveloped areas.

Public Awareness/ Education

This technique involves the development and dissemination of educational materials to residents within the watershed. Public meetings or speakers are another possibility. The goal of this technique is to make residents aware of the systems and processes occuring with their watershed, and to understand their role and impact upon these systems and processes. The hope of this technique is that, once citizens are aware of the potential influence of their activities on the water quality of Jordan Pond, most will take a share of responsibility for its restoration and protection. The group of residents most important to reach are those residing on or near the shoreline of Jordan Pond, but all residents within the watershed can have an impact on water quality.

An important first step in the public awareness/ education process was the formulation of the Jordan Pond Watershed Association. The Association will likely be the key to any public awareness/ education campaign.

The public awareness program should focus on the following objectives:

- To alert the public of the direct correlation between actions within the watershed and impairment of recreational uses of their pond;
- To identify and explain threats to the water quality of Jordan Pond;
- To explain ways in which residents can participate in watershed protection on an individual basis (e.g.: lawn fertilization practices, household hazardous materials disposal, refraining from feeding waterfowl, reducing garbage grinder usage, disposal of pet droppings); and

- To promote the growth and activities of the Jordan Pond Watershed Association.

The public education program may take many forms, including:

- Public meetings, Awarenes Days, speakers, or workshops;
- The creation of an internet site for Jordan Pond, and/or the Jordan Pond Watershed Association;
- Activities for school children;
- Newsletters or fliers;
- Information provided through the media; and
- Progress reports citing periodic water quality testing results.

Catch Basin Stencils

Catch basin stencils are one of the most efficient source controls in-terms of cost and benefits. Catch basin stencilling involves painting notices to residents on the sidewalk or street, adjacent to catch basins, which informs people of the eventual fate of stormwater and contaminants that enter the catch basin. For example, "Don't Dump! Drains to Jordan Pond." A catch basin stencilling program is a great project for scouting groups, community organizations, youth groups, or school children. In addition, a catch basin stencilling program is a simple means of public outreach, involvement, and education, and may also satisfy some requirements of the NPDES Phase 2 stormwater program. With volunteers performing the work, the cost to the Town for a catch basin stencilling program is limited to the cost of materials (e.g.: spray paint, plywood for stencils).

8.20 TRANSPORT MITIGATION

Transport mitigation measures are designed to prevent pollutants already generated within the watershed from entering Jordan Pond. These measures are applied in addition to source control measures, or where a direct reduction or elimination of sources is impossible. These measures often incorporate the filtration or removal of suspended materials as a treatment technique.

Vegetated Shoreline Buffers

A key topic to bring to the attention of shoreline property owners is the value of a vegetated shoreline buffer for protecting water quality. A strip of vegetation left undisturbed along the shoreline functions to intercept and remove nutrients and suspended solids in stormwater runoff. The native vegetation in some areas of the Jordan Pond shoreline has been thinned or removed to create the beach and adjacent roadways located north of the Pond, but, for the most part, an acceptable shoreline buffer area exists around Jordan Pond. Shorelines denuded of vegetation are a source of and an excellent pathway for pollutants to enter the Pond. Vegetated buffer strips serve to filter out a portion of the particulate matter and nutrients in surface runoff, and also serve to decrease the velocity of the runoff. Vegetated shoreline buffers are particularly important in the northeast corner of Jordan Pond, near the dirt-surfaced roadway and driveways. A healthy, full vegetated buffer in this area would serve to trap and filter much of the runoff and eroded material eminating from the road and driveways.

Detention Ponds & Created Wetlands

Detention ponds are small, constructed basins designed to contain incoming stormwater runoff for a limited time period to allow for the settling of some suspended materials and biological uptake of some nutrients. Created wetlands are shallow, inundated areas planted with native wetlands species designed to remove stormwater pollutants via vegetative filtration, nutrient uptake, soil binding, bacterial decomposition, and settling. The land requirements for this style of stormwater treatment is quite large; detention ponds are most effective when they represent 2 to 10 percent of the watershed area from which they collect stormwater. For reference, Jordan Pond is approximately 10 percent of its watershed area. Both detention ponds and created wetlands have been proven to be highly effective means of stormwater treatment. However, the limited space available in the Jordan Pond watershed, especially in the vicinity of the two stormwater outfall pipes at the northern end of the Pond, render detention ponds, sediment forebays, created wetlands, and similar fixtures impractical for implementation at Jordan Pond.

Street Sweeping/ Catch Basin Cleaning

A non-construction method for improving the stormwater quality in the Jordan Pond watershed is to target the area for more frequent street sweeping and catch basin maintenance. If the Jordan Pond watershed area is given high priority for maintenance in the spring, much of the sand from winter applications can be removed before spring storms wash it into the Pond. In addition, an aggressive catch basin cleanout and street sweeping program helps to reduce the amount of roadway particulate matter and pet waste on the roadways which reaches Jordan Pond via stormwater runoff. Intensified street sweeping and catch basin maintenance requires increased utilization of equipment and personnel on the part of the Town of Shrewsbury DPW.

Catch basin cleaning should ideally be undertaken on a semi-annual cycle (i.e.: twice a year) to realize the greatest improvements in stormwater quality; in reality, many communities clean the system's catch basins on a multi-year, rotating basis. An annual clean out program with the Jordan Pond watershed is a more reasonable goal. Catch basin clean out and street sweeping are not effective pond management options on their own. Rather, they should be included as part of any watershed program and normal roadway maintenance program.

In-line Stormwater Treatment

GZA recommends water quality inlets, in the form of modified manholes, be installed at the two stormwater discharge outfalls at the northen end of Jordan Pond. Modified manholes are a method of upstream stormwater treatment within the existing stormdrain line. The Stormceptor® structure, and other equivalent proprietary systems are the most commonly used types, and are similar to conventional manholes, but act as pollution prevention devicse that are designed to remove 60 to 80 percent of total suspended solids and 70 to 100 percent of floatable oil and grease from the stormwater. In addition to removing solids, such devices also remove any nutrients or other contaminants which are sorbed to that particulate matter. The manhole consists of three sections: a separation/ storage chamber at the bottom; a bypass chamber above; and a central maintenance shaft that rises through the first two sections to street level. It is designed to be installed like a conventional manhole, and replaces oil-grit separators, sand filters, and other more complex in-line devices. These devices are also intended to trap fuel oil and hazardous materials in the event of an accidental spill. The design has been extensively tested and approved by the U.S. Environmental Protection Agency, and has been installed in many locations throughout New England. Stormceptor units cost approximately $8,000 to $40,000, excluding design and installation. In-line stormwater treatment devices require a similar maintenance and clean-out program as catch basins. Alternatively, multiple smaller in-line stormwater treatment units could be installed elsewhere in the stormwater drainage network, potentially resulting in increased removal efficiencies.

9.00 POND MANAGEMENT OPTIONS

9.10 PHYSICAL MANAGEMENT CONTROLS

This section contains a basic discussion of several physical in-pond management options available. Implementation of these methods will require additional assessment and planning beyond the scope of this report.

Mechanical Harvesting/Hydroraking

Mechanical harvesting refers to the physical removal of weeds from a body of water. Mechanical harvesting and similar techniques treat the symptoms of poor water quality and aquatic plant infestation, but not the causes; these management techniques do not address nutrient loading from the watershed and sediment. This can be done in several ways, depending on the goals and available budget. Manual raking of weeds from shallow water or boat dock areas can be accomplished by individual homeowners. Harvesting can also be done by divers working underwater using their hands to uproot submerged weeds. Wide-scale harvesting involves specialized, pontoon-mounted equipment. Manual harvesting is only suitable for application to small areas unless a coordinated effort is undertaken among a large number of property owners and lake users. Typically, lake-wide mechanical harvesting is done by a contractor using special machinery.

A standard harvesting machine has a cutting bar mounted in the front that can be lowered to a maximum cutting depth of 5 to 7 feet. Harvesters can operate in water depths as shallow as 1.0 to 1.5 feet. The vegetation is cut just above the substrate (roots left intact and sediment left undisturbed) and then the cut vegetation is conveyed up onto the hull by a belt. Accumulated plant biomass is routinely offloaded to a designated shoreline area for dewatering. Ultimately this biomass must be trucked away, but is suitable for composting.

Harvesting is highly effective in controlling plant infestations over the short term and has the advantage of being able to selectively cut areas of high priority for recreation. The cost of this technique can range from $350-$600 per acre, and effective control over a summer season may require 2 or 3 cuttings. Thus, harvesting at Jordan Pond will likely cost between $25,000 and $40,000 per season, excluding permitting and engineering.

Hydroraking is also a mechanical technique for removing aquatic plants, which entails the use of a pontoon-mounted backhoe with several rake attachments of differing sizes and functions. In addition to removing plant biomass above the sediment, hydroraking has the added advantage of removing roots, tubers, and other plant tissues within the sediment. This technique can also be used to remove accumulations of unconsolidated bottom debris such as decaying leaves, peat, and organic mud. Hydrorakes can operate in water depths as shallow as 1.0 to 1.5 feet and can remove vegetation and bottom debris at or near the surface down to a maximum depth of about 12 feet.

Due to the fact that the hydrorake works from the water, it can access coves and shoreline areas inaccessible to conventional equipment. It can be particularly effective at clearing individual property beach front areas and boat lanes, though this is not applicable at Jordan Pond. Clearing an area of 50 by 75 feet takes the hydrorake approximately 1.5 to 2.0 hours, depending on weed densities. The hydrorake deposits each rake-full load (maximum of 500 pounds) directly on shore or onto a companion barge. The raked material can be disposed of on upland areas or can be trucked away. Often this material is suitable for composting.

Hydroraking is effective in controlling plant infestations over a longer period than harvesting due to the removal of plant root tissue. It is a more expensive technique than harvesting, ranging from $1,500 to $2,500 per acre, or $30,000 to $55,000 for the entirety of Jordan Pond, excluding permitting and engineering.

The major problem with mechanical harvesting, particularly when using floating machinery, is that considerable amounts of floating plant debris can be generated. This debris is not only an annoyance, but can actually lead to re-establishment of weeds elsewhere in the lake – even in areas where there were previously no weeds. This process is known as vegetative fragmentation. Floating barriers can be deployed to attempt to reduce vegetative fragmentation, but these are not 100 percent effective. At Jordan Pond, vegetative fragmentation is not a major concern since Elodea coverage is already essentially 100 percent.

Rotovation

Rotovation is a mechanical technique similar to hydroraking that incorporates the use of an underwater, rototiller-like blade that churns the upper 6 to 9 inches of sediment. The added benefit of rotovation is that is has the potential to dislodge and destroy the root crowns of rooted aquatic plants. Rotovation is most effective in winter and spring when aquatic vegetation is at a minimum, but rotovation may be accomplished in the summer and fall with slightly elevated level of effort and costs. Typical production is 2 to 3 acres per day. The benefits and disadvantages of rotovation include those associated with hydroraking. An additional environmental consideration of rotovation is the potential release of nutrients and buried toxic materials from the sediment. Control achieved by rotovation generally lasts two to three seasons. Rotovation is slightly more costly than hydroraking, typically ranging from $2,000 to $3,000 per acre, or $40,000 to $60,000 for Jordan Pond, excluding permitting and engineering.

Benthic Barriers

Benthic barriers are sheets or screens of various materials and construction that control rooted aquatic plants by compression and light limitation when installed on top of sediments. Such barriers may require some maintenance (releasing trapped gases, repinning to substrate, clearing sediment), but can provide complete control for many years if left in place. If deployed on an annual basis, coverage of the substrate for at least 30 days of the growing season will generally prevent the growth of dense accumulations of weeds. Benthic barriers are best installed in the early spring, when the biomass of existing weed beds are near the seasonal minimum.

They are appropriate only for small areas of the pond or lake bottom, especially in beach and swimming areas, due to relatively high costs for the barrier and its installation. Barrier materials are available in sheets measuring 20 by 100 feet (other sizes also available) and cost about $0.40/square foot. However, costs range from $0.80 to $1.20 per square foot with professional installation. Full coverage at Jordan Pond would likely cost $700,000 to over $1,000,000, plus the cost of permitting, engineering, and regular maintenance. If initial installations are done professionally, accompanied by training of a local summer crew, subsequent maintenance and repositioning efforts could be done at reduced cost. Benthic barriers offer effective, relatively long-term control and may be the best choice for managing weed growth at locations where recreational use and access to open water is significantly impaired. The cost of such barriers makes them impractical for widespread use at Jordan Pond.

Shading/ Light Attenuation

Reducing the amount of available sunlight or the depth of light penetration in the water column are means of controlling rooted aquatic plants. Specially formulated environmental dyes can be used to achieve these goals in natural waterbodies. Dyes work by artificially decreasing the clarity of the surface water, thus limiting the depth of light penetration and therefore limiting the areas where rooted aquatic plants are able to grow. Dyes are ineffective in shallow water (less than 4 feet), can not be used to target individual species, are potentially aesthetically objectionable to recreational users and fishermen, and must be reapplied as the dyed water flushes out of the system. Dyes are not likely an appropriate control option at Jordan Pond.

Drawdown

Drawdown, or intentional lowering the water level, is one means of controlling aquatic vegetation in a lake or pond. Drawdown exposes bottom sediments to prolonged drying. When the drawdown lasts long enough, the technique can kill some rooted plants. Wintertime drawdown can also cause sediment freezing and heaving, and, under ideal conditions, kill plant roots and seeds as well. Wintertime drawdown is the most common application of water level manipulation in the Northeast, and has been proposed for nearby Flint Pond. Generally speaking, pond drawdown is a relatively inexpensive management technique, provided the necessary hydraulic controls exist and are functional. According to the new draft DEM lake management manual, "Drawdown has been found to be effective on some species of aquatic plants, but it can also have negative impacts on the lake environment."[6]

The most significant potential negative impacts of water level drawdown include: fish kills, decreased water quality in the reduced pond volume during drawdown, possible release of sediment contaminants and nutrients, impacts on bordering vegetated wetlands, and regional groundwater concerns.

Drawdown, although an attractive pond management option, is considered to be infeasible at Jordan Pond due to the hydrology and hydraulics of the Pond, the nature of the aquatic vegetation, and the existing sediment quality. First, because of the lack of a formal hydraulic control structure, water from Jordan Pond would have to be siphoned into the outlet channel. In addition, it is likely that drawing down the water level in Jordan Pond will result in increased groundwater inflows to the Pond, thus requiring additional, ongoing dewatering. Second, dewatering is most effective in controlling rooted vegetation in the littoral (shallow) zone of a pond; Jordan Pond has nearly 100 percent coverage of rooted aquatic vegetation, the majority of which would not be affected by drawdown. Third, the quality of the sediment at Jordan Pond is such that exposing and agitating it may be undesirable.

Hypolimnetic Aeration

Sufficient dissolved oxygen in the hypolimnion is important for fish and for preventing or minimizing the release of phosphorus from the pond sediments. One method to ensure sufficient hypolimnetic levels is by artificial aeration or oxygenation of the hypolimnion, where air or oxygen is pumped, via compressor, from the shoreline or floats, down to

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[6] Commonwealth of Massachusetts. 1999. *DRAFT Generic Environmental Impact Report on Lake Management*. "Section 4.1, Methods to Control Aquatic Plants – Drawdown." pp. 139-140.

various depths in the water column. Artificial aeration is deemed to be an inappropriate in-pond management technique for Jordan Pond for two reasons: 1) the physical presence of the compressors and distribution system may be objectionable to residents and recreational users; and 2) aeration will have little to no effect on rooted aquatic plant growth, a major problem at Jordan Pond, as these plants derive their nutrients largely from the sediment, not the water column.

Sediment Removal/Dredging

Removal of benthic (i.e., bottom) sediments by dredging essentially reverses the process of aging in a water body. Dredging, either by mechanical or hydraulic methods, can be conducted as a lake rehabilitation technique to deepen the impoundment and/or to aid in the reduction of nutrient cycling within the aquatic system. The factors reviewed in assessing dredging alternatives typically include the following:

- physical characteristics of the material to be dredged;
- quantities of dredged material;
- dredging depth;
- distance to disposal area;
- physical environment of (and between) the dredging and disposal areas;
- contamination levels in sediments;
- method of disposal;
- required production and types of dredges available.

Dredging and associated activities may have complex impacts on the ecosystem at Jordan Pond. Impacts of dredging fall into two general categories: the effect of removal of bottom materials, and the effects of the extracted materials either during the removal process or after they have been dumped as spoil. A list of possible effects of dredging and placement of dredge spoil include:

- Modification of pond bottom topography
- Modification of water circulation patterns
- Increased turbidity of water
- Increased oxygen demand
- Reduced water temperature
- Reduced light penetration
- Reduced photosynthetic oxygen production
- Release of toxic organic compounds
- Release of pesticides, heavy metals, and hydrogen sulfide
- Increased temperature
- Bottom siltation with very fine sediments

As evident from the list of factors to be considered for a dredging project, this technique is generally the most complex in terms of planning and regulatory issues, as well as one of the most expensive. The benefits of dredging include increased depth and a potential reduction in the amount of nutrient rich sediments. There are also potential short-term detrimental environmental effects during dredging from turbidity, suspended solids, temperature changes, and low dissolved oxygen concentrations. Sediment quality is also an important consideration. If contaminates are found in the sediment, the cost of disposal of dredged material increases dramatically.

The cost of dredging is highly dependent on numerous site-specific factors, including: volume of dredged material, type of dredging equipment utilized, sediment quality, and availability of nearby land for dewatering operations. The volume of soft sediment at Jordan Pond is greater than 183,000 cubic yards (CY). Assuming a $10/CY cost for dredging at a project of this magnitude, and a cost of $12/CY for transport to and disposal at a landfill, the total cost is $22/CY. Landfill disposal is likely required based on the low-level contamination found in the sediment, which renders the material inappropriate for fill. In addition, the permitting and engineering required by a dredging project will likely cost an additional $100,000. Therefore, the total cost of dredging at Jordan Pond is likely to be greater than $4.0 million. The absence of a suitable local landfill for disposal of the dredge spoils could potentially increase the cost of dredging by a factor of two or more. Full dredging of Jordan Pond is deemed to be prohibitably expensive and impractical.

Reverse Layering

Reverse layering (a.k.a. subsidence dredging) is a promising new technology aimed at providing similar benefits as dredging with lower associated costs. Reverse layering is the process whereby sand deposits present below the soft sediment layer of a pond are pumped up though and deposited on top of the organic sediment layer. The end result of reverse dredging is a thick (approximately 12 inches) layer of “clean”, inorganic sand on top of the pond sediments. The sediments are expected to subside and consolidate somewhat due to the new weight introduced on top and the new reduction in material below. The goal of reverse dredging is to essentially “seal off” the pond sediments, thus limiting the potential release of nutrients or contaminants into the water column. In addition, the new pond substrate is likely to be aesthetically favorable to recreational users (especially those fishing and swimming), and inhospitable to rooted aquatic plants. Dr. William Kerfoot, president of K-V Associates of Mashpee, holds U.S. Patent No. 5,428,908 on the “Apparatus and method for subsidence deepening” (Kerfoot 1995).

Reverse layering requires additional investigations and engineering beyond those needed for dredging, including: multiple sediment borings to locate and characterize the sand layer beneath the pond sediments (assumed present based on surficial geology maps); and a ground-penetrating radar survey to locate any cobbles, boulders, or archeological artifacts within the sand layer. Since the sand material removed from the pond sub-bottom is deposited on-site (over the pond sediments), no material is removed from the pond. Therefore, no dewatering or transport of dredged spoils is required, allowing for a significant cost savings over traditional dredging. Also, the total volume of material "dredged" and re-applied via reverse layering at Jordan Pond would be significantly less than via traditional dredging, roughly 34,000 CY versus over 183,000 CY. Although dependant on additional site-specific constraints, the costs associated with reverse layering at Jordan Pond are expected to be $600,000 to $1,000,000; these estimated costs are approximately 1/6 to 1/3 those related to traditional dredging operations and disposal. GZA recommends that the feasibility of reverse layering be further investigated in Phase 2 of this study.

9.20 CHEMICAL MANAGEMENT CONTROLS

A number of herbicides are effective for controlling various species of macrophyte and are approved by the EPA and the Massachusetts DEP for aquatic application. In the case of Jordan Pond, where the area of dense growth is contiguous, a fluridone-based herbicide known as Sonar is typically considered a good choice. Herbicide treatments can provide control of target "weeds" for one to three years. This technique is relatively inexpensive, at an estimated cost of $500 to $1,000 per acre treated, or $10,000 to $20,000 for complete coverage of Jordan Pond. Fluridone-based herbicides are typically ineffective in controlling algal growth.

An endothall-based treatment such as Hydrothol 191 is another potential option for the chemical treatment of Jordan Pond. Hydrothol 191 is composed of the amine salt of endothall, and is similar to Aquathol. The advantage of Hydrothol is that it acts as both an herbicide and algaecide, and is likely to help control both the Elodea and Bluegreen algae at Jordan Pond. Hydrothol costs approximately $300 to $500 per acre treated, or $6,000 to $10,000 for complete coverage of Jordan Pond, excluding permitting and engineering. Copper sulfate is another potential algaecide for Jordan Pond, and costs approximately $200 per acre treated.

Despite the effectiveness and relatively low cost of chemical management controls, they have a number of disadvantages. Foremost among these are public misgivings and aversion to the use of chemicals. A public forum is recommended to gauge the acceptability of this technique and to educate concerned citizens before implementation could be considered. Potential drawbacks of this technique include the release of nutrients into the water as the plants die, temporary conflicts with recreational uses of the reservoir, and stringent permitting requirements. Additionally, the macrophyte growth in the Pond likely functions as one of the main spawning areas for certain fish species and as a nursery area for fingerlings of all species.

9.30 BIOLOGICAL MANAGEMENT CONTROLS

Biological control mechanisms refer to the introduction of new organisms into a body of water to reduce the coverage or density of nuisance aquatic plants. Biological organisms with the potential to control aquatic plants include insects, pathogens, snails, and fish. One of the most commonly used is the triploid grass carp (*Ctenopharyngodon idella*), which is a sterile fish that feeds on virtually all types of aquatic plants. The main concern with the introduction of grass carp is that they are capable of stripping a lake or pond of all vegetation without distinguishing between beneficial and nuisance species. The possession and use of grass carp is prohibited in Massachusetts, and is therefore obviously not applicable at Jordan Pond.

10.00 JORDAN POND MANAGEMENT RECOMMENDATIONS

The goals of the proposed Jordan Pond management plan are:

- Reduce nutrient and solids loading, in addition to other contaminants, from the Jordan Pond watershed;
- Reduce the impact of waterfowl on water quality in Jordan Pond with respect to bacterial and nutrient loading;
- Improve the aesthetics of Jordan Pond, including water clarity and the presence and extent of algal and other aquatic vegetation;
- Reduce the impact of phosphorus cycling from the Pond sediment; and
- Improve the quality of the habitat at Jordan Pond for fish and other fauna.

At present, restoring the water quality in Jordan Pond to meet state health code and standards for primary contact recreation is not one of the recommended goals of the management plan. Based on GZA's analysis of historic bacteria level data, our recent water quality sampling and testing, and our bacteria loading model, it is GZA's opinion that Jordan Pond is unlikely to consistently meet state swimming standards, even with more formalized watershed management. GZA therefore recommends that the use of Jordan Pond as a public swimming facility be eliminated from consideration. This decision reflects the opinion expressed by local residents and stakeholders in the project kickoff meeting, held on October 16, 2002. Following the successful implementation of the following management recommendations, the possibility of restoring Jordan Pond for contact recreation (i.e.: swimming) can be reevaluated.

10.10 WATERSHED MANAGEMENT RECOMMENDATIONS

The eutrophication of lakes and ponds is a naturally occurring process which typically takes places over thousands of years. Anthropogenic impacts have greatly accelerated this process in many area water bodies, and Jordan Pond is no exception. The best way to reduce negative impacts on urban water bodies is by working to curtail the introduction of new nutrients and pollutants from the watershed. Thus, watershed controls are paramount to any successful management plan and pond restoration program, including the Jordan Pond Management Plan. Many watershed management techniques can add environmental benefits beyond those applicable to pond restoration, many are common sense, and others are simply good housekeeping practices.

GZA recommends that the Town of Shrewsbury, in conjunction with the Jordan Pond Watershed Association work with the residents of the Jordan Pond watershed to reduce the nutrient, contaminant, and solids loading to Jordan Pond. The recommended watershed controls include:

1. Expand existing public education, awareness, and outreach programs.
2. Develop additional such programs as necessary, including informational brochures and signage around the Pond. Educational efforts should focus especially on turf management, pet waste disposal, garbage disposal use, and hazardous materials disposal.
3. Modify street sweeping and catch basin cleaning programs to operate on an annual cycle (one time per year). Streets within the Jordan Pond watershed should be given high priority for maintenance in the spring so that much of the sand from winter applications can be removed before spring storms wash it into the Pond.
4. Enforce the ban on motorized vehicles on the trails adjacent to the Pond.
5. Relandscape the beach area to minimize erosion (see Section 10.20).
6. Hold workshops on turf management and consider the creation of a rebate system for the purchase of phosphorus-free fertilizers.
7. Stencil catch basins in the watershed.
8. Install "pooper-scooper" signage and enforce pet waste disposal regulations.
9. Install an in-line stormwater treatment device at each of the two concrete discharge pipes at the northern end of the Pond (or multiple smaller devices elsewhere within the stormwater conveyance system).

10.20 WATERFOWL MANAGEMENT RECOMMENDATIONS

Based on the considerations discussed in Section 6.00, GZA recommends the following waterfowl control options for Jordan Pond:

Beach Habitat Modification

Given GZA's recommendation to suspend the use of Jordan Pond as a swimming facility, the beach area can be reconfigured. Refer to Figure 10-1 for a conceptual sketch of GZA's proposed beach habitat modification. The installation of a boulder wall at the Pond's edge in the vicinity of the beach would prevent geese from walking from the Pond onto beach. The lack of such a suitably visible transition zone is also a deterrent to airborne geese and migratory geese searching for a resting or foraging place. The beach area could be relandscaped with native shrubbery, grasses, or trees in such a manner as to discourage the nesting and foraging of geese, while providing a small, pleasant park for the residents of Shrewsbury; the relandscaped beach area could potentially be an expansion of the existing Jordan Pond Park, and would have the added benefit of reducing erosion currently occurring from the southern portion of the watershed into the Pond. A vegetated buffer strip could be planted adjacent to the boulder wall to further reduce nutrient and total suspended solids (TSS) loading to the Pond. Possible amenities at the relandscaped beach area include: benches, playground equipment, boat dock(s), and/or a boat ramp.

For the beach area, replanting with native vegetation is recommended. Nurseries and landscaping companies can usually provide native shrubs and ground cover that are adapted to the shoreline environment. A wider vegetated buffer strip (greater than 100 feet) is more effective in pollutant attenuation that a narrow buffer, but even a buffer only a few feet wide provides some benefit. Fertilizers and pesticides should not be used in the buffer. In addition to mitigating the impacts of stormwater runoff, vegetated buffers reduce landscape maintenance requirements and provide habitat for (non-goose) wildlife.

Volunteer Trained Goose Dog Program

GZA recommends that the Town of Shrewsbury seek the assistance of local dog-owning residents for goose control at Jordan Pond. The Border collie has traditionally been the most successful breed of dog for goose control, but any dog with sufficient energy and a love of water is acceptable. The Town could provide instruction and training for the owner and dog and outfit the volunteer pair with any necessary equipment and/or vaccinations. In exchange, the dog and owner could visit the Pond as part of their normal daily exercise routine to provide some level of hazing. Trained goose dogs are one of the most effective waterfowl alternatives, but the cost of owning and raising a dog and paying for a handler can be high. A volunteer program is a low-cost, long-term alternative that still affords successful goose control.

10.30 IN-POND MANAGEMENT RECOMMENDATIONS

Jordan Pond is a small, urban pond with a long history of water quality impairments. Various watershed and in-pond management techniques have been implemented throughout the last 50 years with mixed success. The Town of Shrewsbury, the members of the Jordan Pond Watershed Association, local residents, and other potential stakeholders have an important choice to make regarding the future of their Pond, its water quality, its role as a local resource for recreation, its suitability as habitat for flora and fauna, and its overall value to the Town. Three broad categories of in-pond actions are possible: 1) No Action; 2) Small-scale, short-term management actions (such as repeated herbicide applications and/or hydroraking); and 3) Intensive, large-scale, long-term management actions (such as dredging or water diversion).

No Action Alternative

Given the current impaired state of Jordan Pond and the desires expressed by various stakeholders, GZA does not recommend the “No Action” alternative for in-pond management at Jordan Pond. If no action is taken, the water quality in the Pond would continue to degrade and aquatic vegetation would continue to grow unchecked.

Small-Scale Management Actions

A low-cost in-pond management option for Jordan Pond would be to continue with repeated annual herbicide/algaecide applications. An endothall-based treatment such as Hydrothol 191 is recommended. Hydrothol costs approximately $300 to $500 per acre treated, or $6,000 to $10,000 for complete coverage of Jordan Pond. Herbicide treatment has been used with reasonable success in Jordan Pond in the past to control aquatic vegetation, but the benefits of such treatments are short-term. Thus, annual or bi-annual (every other year) herbicide/algaecide treatments would be most effective. Mechanical aquatic plant control, such as hydroraking, is another small-scale, short-term management option, and may be useful in combination with herbicide/algaecide treatments. In the absence of more involved in-pond management techniques, herbicide/algaecide treatments are the recommended management option for Jordan Pond, but it should be recognized that this option will require continual retreatments and management efforts.

Large-Scale Management Actions

A truly effective, long-term, in-pond management program at Jordan Pond is likely to be an expensive, complex process. Implementation of such a program requires careful analysis and frank discussions of what the value and intended future role of Jordan Pond is to local residents and stakeholders. Should the long-term health of Jordan Pond emerge as the goal of this decision making process, then a large-scale restoration project may be appropriate. GZA believes that the “reverse-layering” process holds the most promise for economical, long-term restoration of Jordan Pond.

10.40 FEASIBILITY STUDY

GZA recommends that Phase 2 of this study, The Preferred Alternative Feasibility Study, focus upon the specific feasibility of implementing reverse layering at Jordan Pond.